Express Mail Label No. EV318163342 US

[0001] DETERMINATION OF CODE TRANSMIT POWER RANGE IN DOWNLINK POWER CONTROL FOR CELLULAR SYSTEMS

[0002] This application claims priority from U.S. Provisional Application No. 60/415,938 and filed on October 3, 2002, which is incorporated by reference as if fully set forth herein.

[0003] FIELD OF THE INVENTION

[0004] This invention generally relates to cellular networks and more particularly to determination of code transmit power for use in power control.

[0005] BACKGROUND OF THE INVENTION

[0006] For a Universal Mobile Telecommunication System (UMTS) system, in the downlink there are a plurality of different codes transmitted for a plurality of different coded Composite Transport Channels (CCTrCHs) transmitting. Each CCTrCH is power controlled independently. At the receiver of the UE (a RAKE receiver is used for frequency division duplex (FDD), a multi-user detector (MUD) receiver is used for time division duplex (TDD)), the difference between the transmit power of two codes in the same cell has to be within a certain range to assure that the receiver works properly. The maximum allowed difference is called the dynamic range of the receiver. Because the total transmit power (i.e., carrier power) in the downlink is limited, an appropriate range of transmit power for each code should be determined to allow the power control to adjust the difference of code transmit powers to be in the dynamic range as much as possible.

[0007] Currently, there is no known convenient algorithm to determine the range of transmit power for each code in the downlink. The consequence of this is that the transmit power of one code can be increased to a very high value by the power control, which makes it difficult for the transmit power of other codes to catch up with the dynamic range due to the limit of Node B total transmitter power.

[0008] It is desirable to provide a method for determining the range of transmit power in the downlink, preferably in the form of an algorithm.

[0009] SUMMARY OF THE INVENTION

[0010] The invention provides a method and apparatus employing an algorithm for determining the range of transmit power for each code in the downlink properly for all modes of UMTS systems (including FDD, high chip rate (HCR) TDD, and low chip rate (LCR) TDD). In a preferred embodiment, the invention provides details of the preferred implementation. While the following description makes reference to downlink power control for CDMA systems as an example, it is to be noted that the invention is applicable for uplink power control and is also usable in cellular systems other than those mentioned above.

[0011] BRIEF DESCRIPTION OF THE DRAWINGS

[0012] A more detailed understanding of the invention may be had from the following description of preferred embodiments, given by way of example and to be understood in conjunction with the accompanying drawing wherein:

[0013] Figure 1 illustrates diagrammatically a first embodiment in the form of a flow chart for determination of code transmit power range in downlink; and

[0014] Figure 2 illustrates diagrammatically a second embodiment in the form of a flow chart.

[0015] The following acronyms are used in the present application:

AWGN	additive white Gaussian noise
BLER	block error rate
CCTrCH	coded composite transport channel
CDMA	code-division multiple access
CRNC	controlling RNC
DR	dynamic range
FDD	frequency-division duplex
HCR	high chip rate
LCR	low chip rate
MUD	multi-user detector
RNC	radio network controller
SIR	signal to interference ratio
TDD	time-division duplex
UE	user equipment
UMTS	universal mobile telecommunications system

[0016] DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0017] Described hereinafter are a method and apparatus employing algorithms in one of the first and second embodiments for determination of code transmit power for downlink power control in cellular networks. The transmit power range lies between the upper bound and lower bound of the transmit power of a particular code. The method of the present invention determines an appropriate transmit power range (especially the upper bound) for each code so that when the transmit power of any code approaches its upper bound, the transmit power of other codes can be adjusted to stay within the dynamic range.

[0018] The solution of two present inventions determines the range of code transmit power using at least some of the following parameters: 1) number of codes in

the downlink (time slot, if TDD); 2) the range of the SIR target of the code; 3) the maximum allowed dynamic range of the receiver used at the UE (dynamic power range of the receiver is the maximum allowed difference between transmit power of any codes); 4) average MUD efficiency factor in the downlink (for TDD only); 5) average orthogonal factor in the downlink (for FDD only); 6) average inter-cell to intra-cell interference ratio.

[0019] The inventive method permits cellular networks to determine the dynamic range of code transmit power in the downlink power control. In particular, it is applicable to all modes of UMTS systems (including FDD, HCR TDD, and LCR TDD).

[0020] The method 100 of the first embodiment, shown in Figure 1, uses the following information to determine the range of code transmit-power:

[0021] The number of codes in the downlink (time slot, if TDD), denoted by N, at step S1 is obtained;

[0022] The range of the SIR target of the code i: the lower bound $SIR_{lb}(i)$ and upper bound $SIR_{ub}(i)$, is then obtained (step S2). The range is determined by the C-RNC from the BLER requirement of service and possible propagation conditions. For example, the upper bound is the SIR target corresponding to the SIR in the worst case (known as case 1 in the technical literature) and the lower bound is the SIR target corresponding to the best case (known as the AWGN case in the technical literature); and

[0023] The maximum allowed dynamic range of the receiver used at the UE is *DR,* the value of which depends on the design of the receiver. Therefore, *DR* is a design parameter that can be configured by the operator.

[0024] The code transmit power range is determined as follows. First, among all the codes, the code with maximum upper bound SIR target, say code *j,* is selected (step S3). The upper bound of the transmit power of code i is denoted by $TXCode_{ub}(i)$ which is used as a reference. The relationship between the upper bound of code transmit

power of code i and code j (the code with maximum upper bound SIR target), obtained at step S4, is expressed as:

[0025] $TXCode_{ub}(i) = R(i) \cdot TXCode_{ub}(j)$ Equation 1

[0026] where $R(i)$, the desired ratio between $TXCode_{ub}(i)$ and $TXCode_{ub}(j)$, is

[0027] $$R(i) = \begin{cases} \frac{SIR_{ub}(i)}{SIR_{ub}(j)} & if\ \frac{SIR_{ub}(j)}{SIR_{ub}(i)} \leq DR \\ \frac{1}{DR} & if\ \frac{SIR_{ub}(j)}{SIR_{ub}(i)} > DR \end{cases}$$ Equation 2

[0028] The sum of upper bound of code transmit power is subject to the limit of maximum Node B carrier power, $CATX_{\max}$, (step S5). For system stability purposes, a margin is used to prevent the total code transmit-power to reach the maximum allowed value. The margin, a design parameter, can be configured by the operator as:

[0029] $$\sum_{i=1}^{N} TXCode_{ub}(i) = CATX_{\max} / Margin$$ Equation 3

[0030] Therefore, the upper bound of the transmit power of code i is given by

[0031] $$TXCode_{ub}(i) = \frac{R(i)}{\sum_{i=1}^{N} R(i)} \left(CATX_{\max} / Margin \right)$$ Equation 4

[0032] The lower bound of code transmit power, obtained at step S6, is set to the minimum allowed carrier power of the Node B.

[0033] $TXCode_{lb}(i) = CATX_{\min}$ Equation 5

[0034] The code transmit powers are then adjusted to lie within the dynamic range (step S7). The method 100 will configure or reconfigure the range of code transmit power whenever the number of codes in the downlink changes, which includes: radio link setup for a new CCTrCH and radio link release for an existing CCTrCH. Accordingly, the method 100 is suitable for a real-time services scenario, where the number of codes changes relatively slowly.

[0035] A second embodiment of a method 200 in accordance with the present invention, shown in Figure 2, uses the following information to determine the range of code transmit power: 1) the number of codes in the downlink (time slot, if TDD), denoted by N; 2) the range of SIR target of the code i: the lower bound $SIR_{lb}(i)$ and upper bound $SIR_{ub}(i)$ which are determined from the BLER requirement; 3) the maximum allowed dynamic range of receiver used at the UE, DR; 4) average MUD efficiency factor in the downlink (for TDD only), α; 5) average orthogonal factor in the downlink (for FDD only), α; 6) average inter-cell to intra-cell interference ratio, η; and 7) maximum allowed load in the downlink, $Load_{\max}$. This is a design parameter that can be configured by the operator and executed by the call admission control function. These data are obtained at steps S11 and S12.

[0036] Code transmit power range is then determined as follows: The current load in the downlink (time slot, if TDD) is computed (S13). Among all the codes, the code with maximum upper bound SIR target, say code j, is selected (step S14).

[0037] The load contributed by each code i is given by:

[0038] $$Load(i) = (1-\alpha+\eta)\cdot SIR_{ub}(i),\ \text{if}\ \frac{SIR_{ub}(j)}{SIR_{ub}(i)} \le DR \quad , \qquad \text{Equation 6}$$

[0039] $$Load(i) = (1-\alpha+\eta)\cdot (SIR_{ub}(j)/DR),\ \text{if}\ \frac{SIR_{ub}(j)}{SIR_{ub}(i)} > DR . \qquad \text{Equation 7}$$

Therefore, the total load is given by:

[0040] $$Load = \sum_{i=1}^{N} Load(i) \qquad \text{Equation 8}$$

[0041] The load in the downlink is controlled by the call admission control function to be no more than the maximum allowed load in the downlink, $Load_{\max}$. The limit for the sum of code transmit power upper bounds, obtained at step S14, is set to be proportional to the current load. That is:

[0042] $\sum_{i=1}^{N} TXCode_{ub}(i) = CATX'_{\max} / Margin$, where Equation 9

[0043] $CATX'_{\max} = \frac{Load}{Load_{\max}} \cdot CATX_{\max}$ Equation 10

[0044] The upper bound of the transmit power of code i is $TXCode_{ub}(i)$. The relationship between the upper bound of code transmit power of code i and code j (the code with the maximum upper bound SIR target, obtained at step S15), is expressed as:

[0045] $TXCode_{ub}(i) = R(i) \cdot TXCode_{ub}(j)$ Equation 11

[0046] Where $R(i)$, the desired ratio between $TXCode_{ub}(i)$ and $TXCode_{ub}(j)$, (obtained at step S16), is:

[0047] $$R(i) = \begin{cases} \frac{SIR_{ub}(i)}{SIR_{ub}(j)} & if \ \frac{SIR_{ub}(j)}{SIR_{ub}(i)} \le DR \\ \frac{1}{DR} & if \ \frac{SIR_{ub}(j)}{SIR_{ub}(i)} > DR \end{cases}$$ Equation 12

[0048] Therefore, the upper bound of transmit power of code i, (obtained at step S17), is given by:

[0049] $TXCode_{ub}(i) = \frac{R(i)}{\sum_{i=1}^{N} R(i)} \left(CATX'_{\max} / Margin \right)$ Equation 13

[0050] Utilizing equation 12 in equations 6-8, the result is:

[0051] $Load = (1 - \alpha + \eta) \cdot SIR_{ub}(j) \cdot \sum_{i=1}^{N} R(i)$ Equation 14

[0052] Likewise, utilizing equation 14 in equation 10 provides:

[0053] $CATX'_{\max} = \frac{(1 - \alpha + \eta) \cdot SIR_{ub}(j) \cdot \sum_{i=1}^{N} R(i)}{Load_{\max}} \cdot CATX_{\max}$ Equation 15

[0054] Finally, utilizing 15 in equation 13 yields:

[0055] $TXCode_{ub}(i) = \frac{(1 - \alpha + \eta) \cdot R(i) \cdot SIR(j)}{Load_{max}} \cdot \frac{CATX_{\max}}{Margin}$ Equation 16

[0056] The lower bound of the code transmit power (obtained at step S18), is set to be the minimum allowed carrier power of the Node B as:

[0057] $TXCode_{lb}(i) = CATX_{\min}$ Equation 17

[0058] The code transmit powers are then adjusted to lie within the dynamic range (step S19).

[0059] The method 200 shown in Figure 2 does not necessarily need to configure or reconfigure the range of code transmit power when the number of codes in the downlink changes. As shown in equation 16, the transmit power range for a code is determined by its SIR upper bound and maximum SIR upper bound of codes in the downlink (time slot, if TDD). As long as the maximum SIR upper bound of codes in the downlink (time slot, if TDD) does not change the value of $R(i) \cdot SIR_{ub}(j)$, the range of code transmit power will not change. As a result, the frequency of reconfiguration of the code transmit power range is much less than the frequency at which the number of codes changes. Therefore, this algorithm is suitable for a non-real-time services scenario, where the number of codes changes quickly. In addition, it is also suitable for a real-time services scenario as well.

[0060] The flow diagram of Figure 1 shows the preferred sequence of operations for implementing the first algorithm. Initially, the number of the codes in the downlink and the maximum allowed dynamic range are obtained, followed by steps which operate on the data obtained to achieve the desired result. However, the steps may be altered in sequence without departing from the scope of the invention.

[0061] The flow diagram of Figure 2 shows the preferred sequence of operations for implementing the second algorithm. The process initially obtains the number of codes in the downlink, the maximum allowed dynamic range, MUD efficiency factor (as applied to TDD only), orthogonal factor (as applied to FDD only), average inter-intracell interference ratio, and maximum allowed load in downlink, followed by

operations on these data to achieve the desired result. Here too, the steps may be altered in sequence without departing from the scope of the invention.

[0062] Even though the above description makes reference to FDD and TDD systems as examples, the invention for downlink power control is applicable to other types of communication systems as well.

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